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Parsa et al.

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(54) **HYBRID DSMA/CDMA (DIGITAL SENSE MULTIPLE ACCESS/CODE DIVISION MULTIPLE ACCESS) METHOD WITH COLLISION RESOLUTION FOR PACKET COMMUNICATIONS**

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(51) **Int. Cl.**[7] **H04B 1/69**; H04B 7/216

(52) **U.S. Cl.** **375/141**; 370/335

(58) **Field of Search** 375/130, 141, 375/146, 147; 370/342, 320, 441, 329, 335; 455/509

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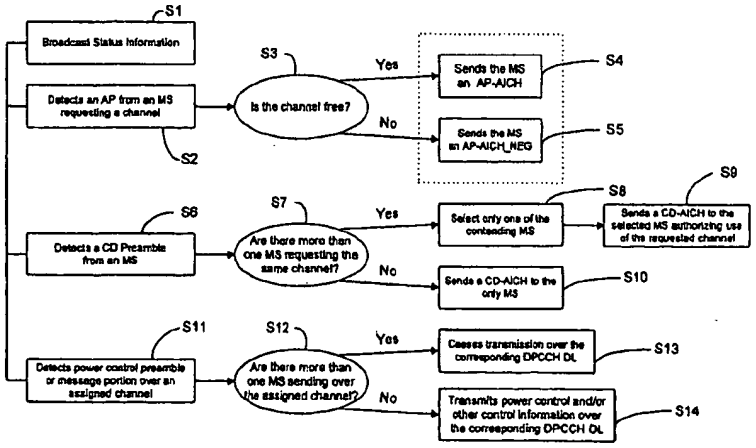
(74) *Attorney, Agent, or Firm*—McDermott, Will & Emery

(57) **ABSTRACT**

A hybrid DSMA-CR/CDMA methodology provides efficient access to one of a group of common packet channels in a cell of a spread spectrum wireless communication network. The base station broadcasts status information as to the availability and/or available data rates for each common packet channel (CPCH) or group of CPCH channels. Each mobile station uses the status information to select an available channel and/or a channel with sufficient data rate. The mobile station then starts transmission of a series of access preambles, each of which contains a signature corresponding to the selected channel. The mobile station transmits the preambles at increasing power levels. When the base station detects a preamble transmission, the base station responds with a corresponding acknowledgment. Upon receiving this acknowledgment, the mobile station preferably selects a collision detection (CD) signature and transmits a CD preamble containing that signature. If the base station receives more that one CD preamble, it selects one and responds by sending back a corresponding CD acknowledgement. In response, the mobile station begins to send its packet data along with any closed loop power control information over the selected CPCH channel. If the MS detects a loss of the downlink channel, the MS halts its CPCH uplink transmission. Also, during a transmission of data, the mobile station that has successfully obtained access can piggy-back data packets one after another so long as it has packets ready to send, up to a maximum limit set by the network.

29 Claims, 10 Drawing Sheets



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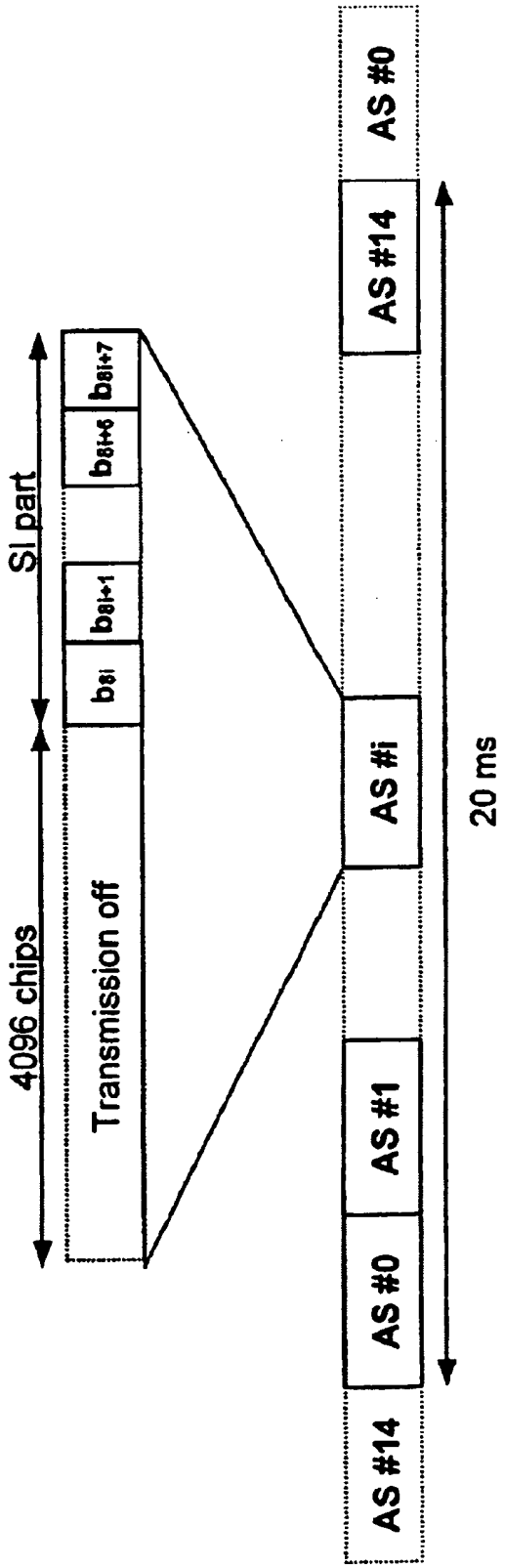
AS #0
AS #14
AS #i
AS #1
AS #0
AS #14
20 ms
SI part
b_{8i}
b_{8i+1}
b_{8i+6}
b_{8i+7}
Transmission off
4096 chips
AS - Accees Slot
SI - Status Indicators

FIG. 1

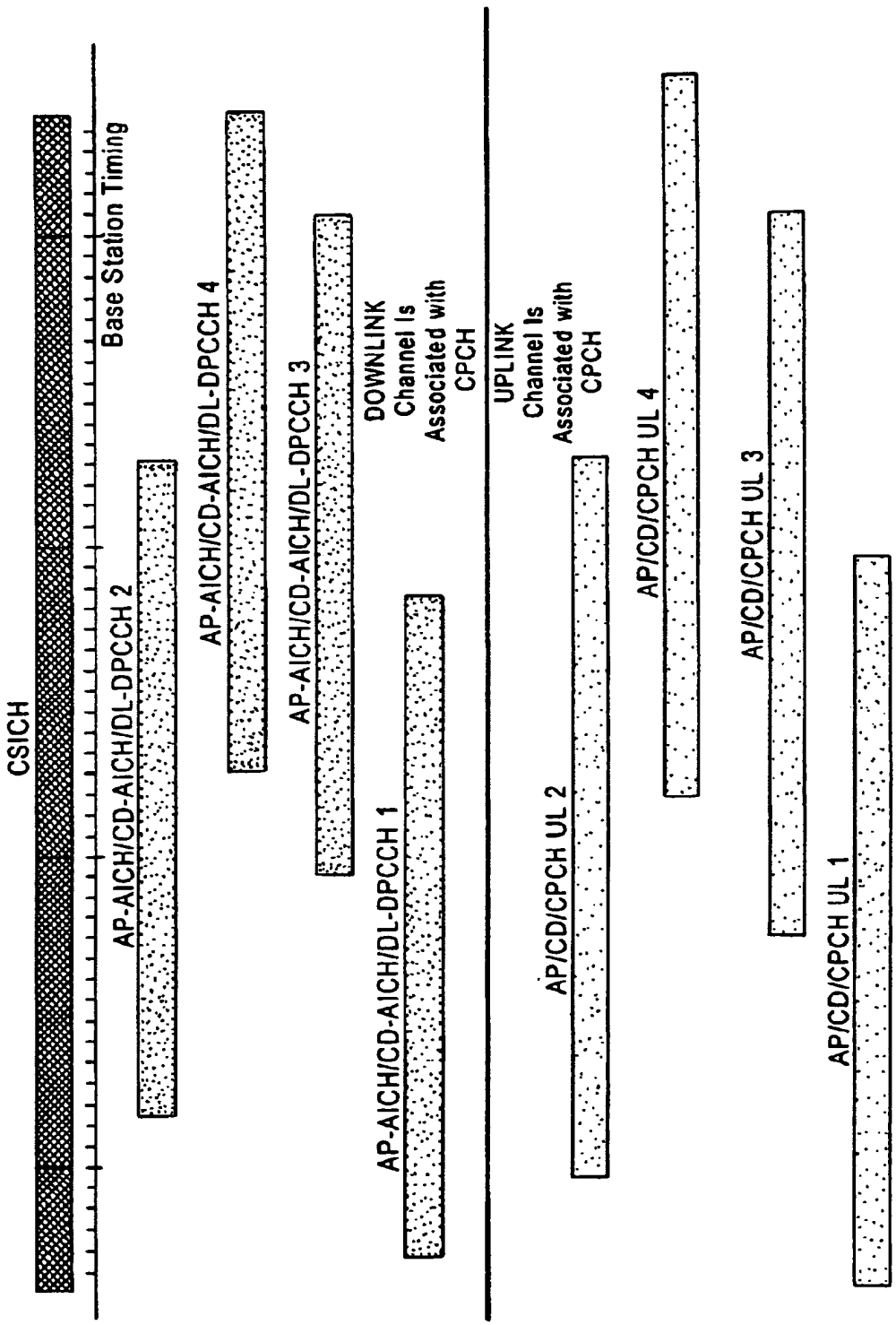
CSICH
Base Station Timing
AP-AICH/CD-AICH/DL-DPCCH 2
AP-AICH/CD-AICH/DL-DPCCH 4
AP-AICH/CD-AICH/DL-DPCCH 3
AP-AICH/CD-AICH/DL-DPCCH 1
DOWNLINK Channel Is Associated with CPCH
UPLINK Channel Is Associated with CPCH
AP/CD/CPCH UL 2
AP/CD/CPCH UL 4
AP/CD/CPCH UL 3
AP/CD/CPCH UL 1

FIG. 2

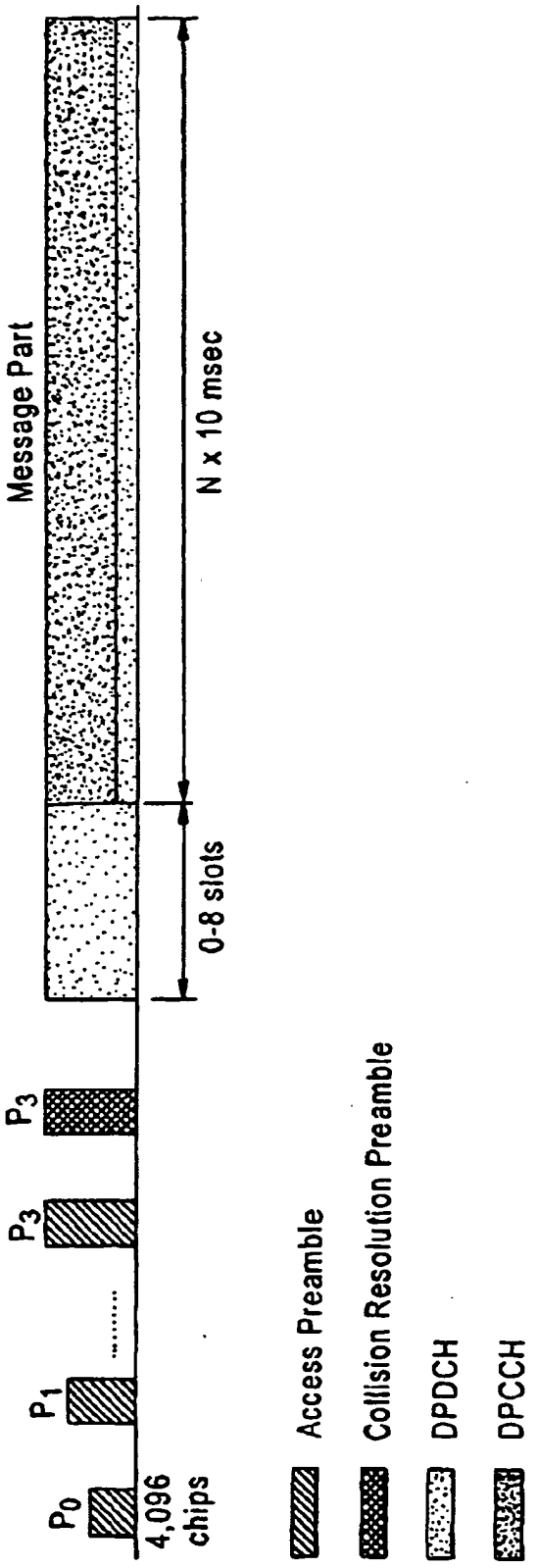
Message Part
N x 10 msec
0-8 slots
P3
P3
P1
P0
4,096 chips
Access Preamble
Collision Resolution Preamble
DPDCH
DPCCH

FIG. 3

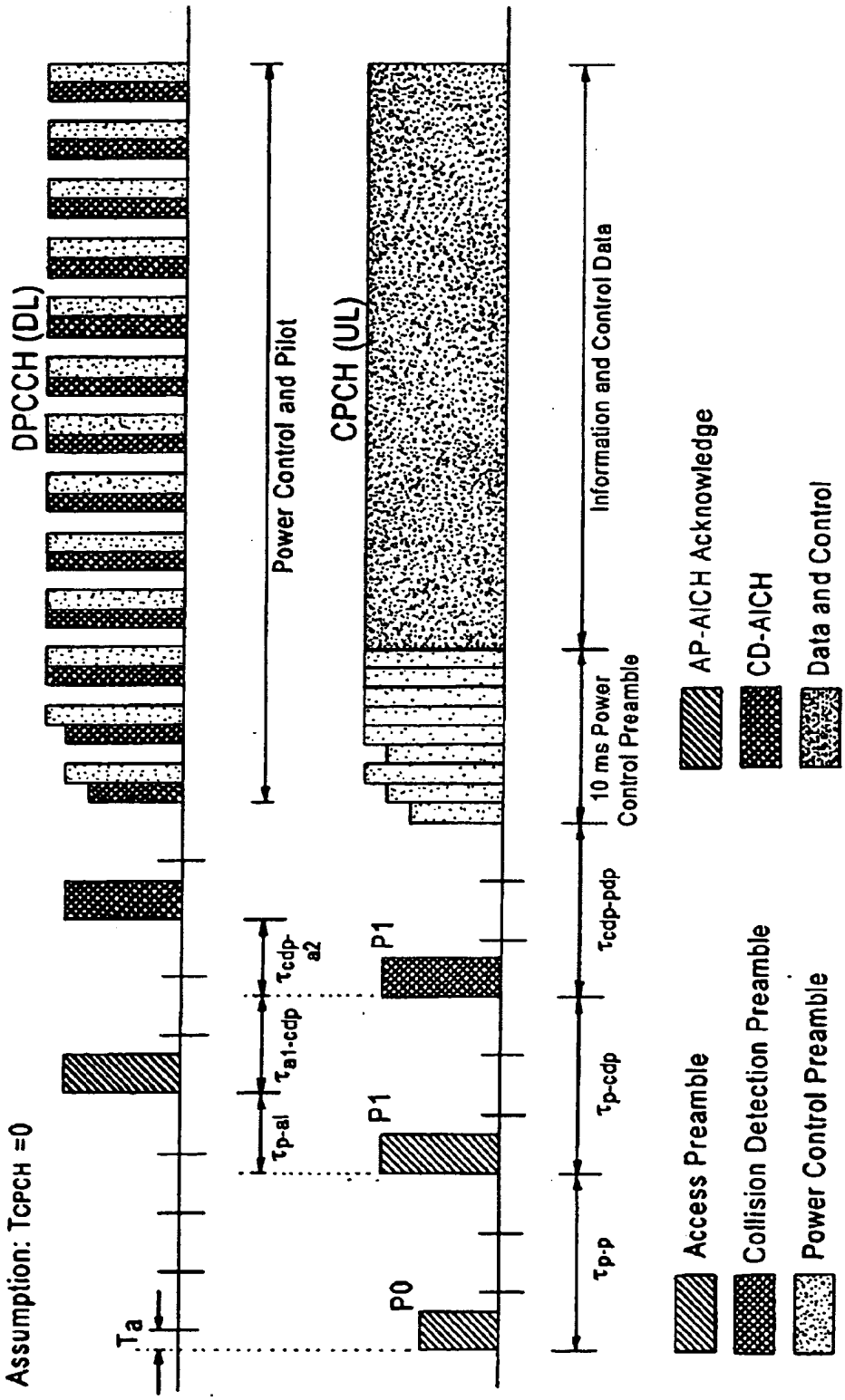
DPCCH (DL)
CPCH (UL)
Power Control and Pilot
Information and Control Data
Assumption: TCPCH =0
Ta
τp-a1
τa1-cdp
τcdp-a2
P1
P1
P0
τp-cdp
τcdp-pdp
10 ms Power Control Preamble
τp-p
Access Preamble
Collision Detection Preamble
Power Control Preamble
AP-AICH Acknowledge
CD-AICH
Data and Control

FIG. 4

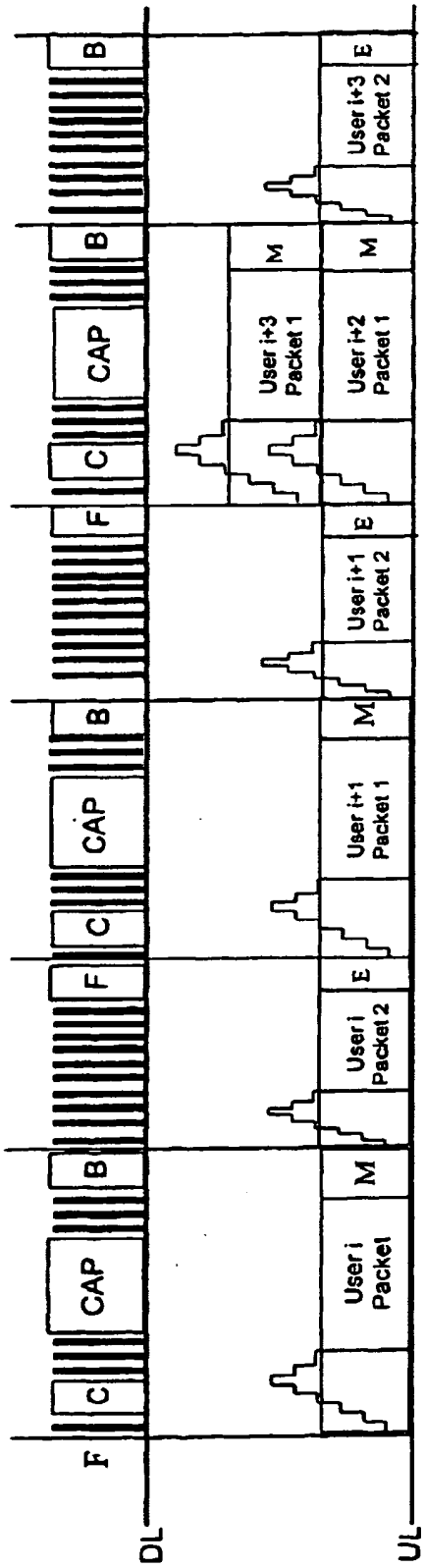
DL
UL
F
C
CAP
B
F
C
CAP
B
F
C
CAP
B
User i Packet
M
User i Packet 2
E
User i+1 Packet 1
M
User i+1 Packet 2
E
User i+2 Packet 1
M
User i+3 Packet 1
M
User i+3 Packet 2
E
F = Free
B = Busy
C = Power Control Begins
CAP = Channel Captured
E = End
M = More

FIG. 5

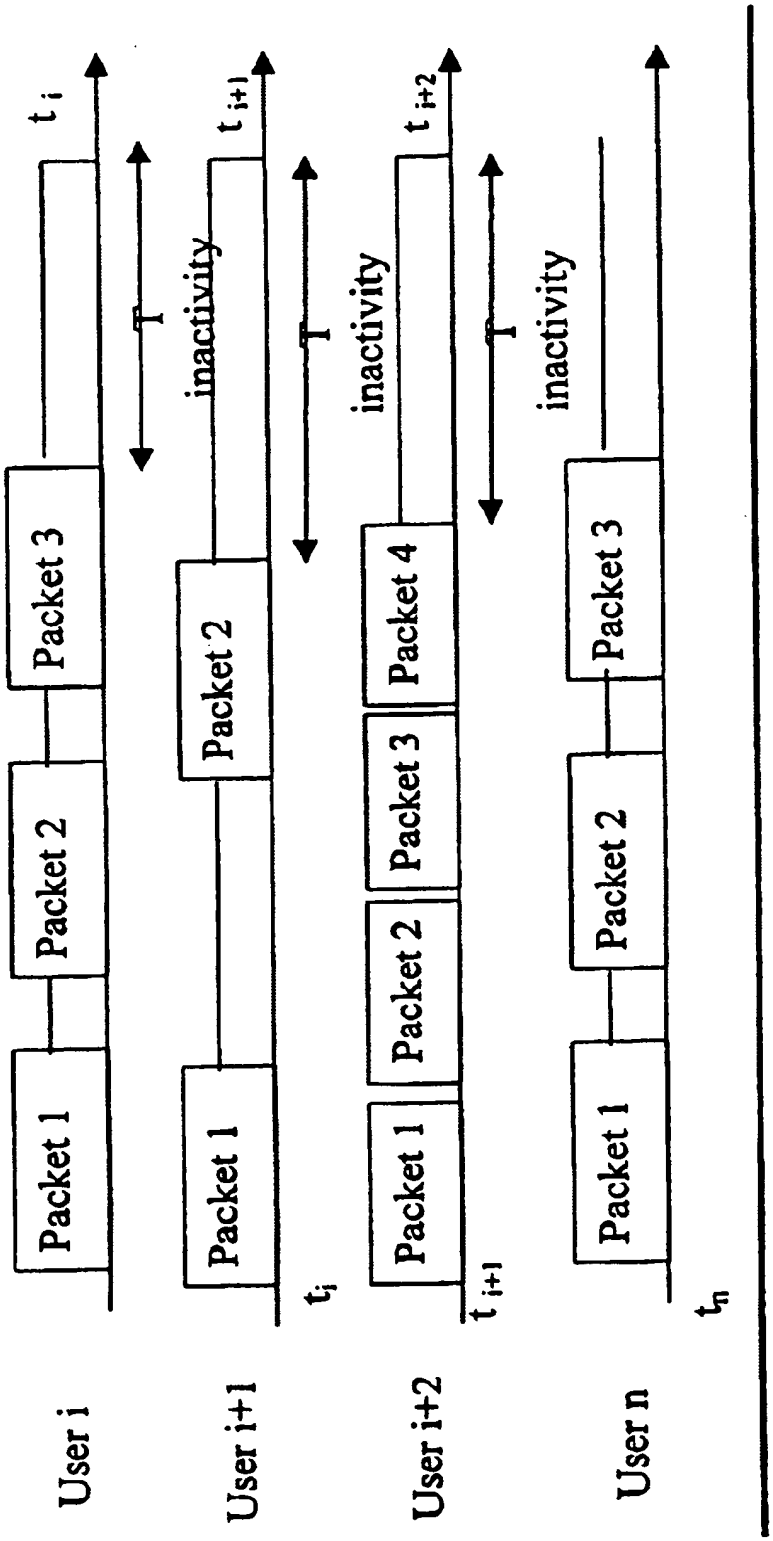
User i
User i+1
User i+2
User n
Packet 1
Packet 2
Packet 3
Packet 4
inactivity
T
t_i
t_{i+1}
t_{i+2}
t_j
t_n

FIG. 6

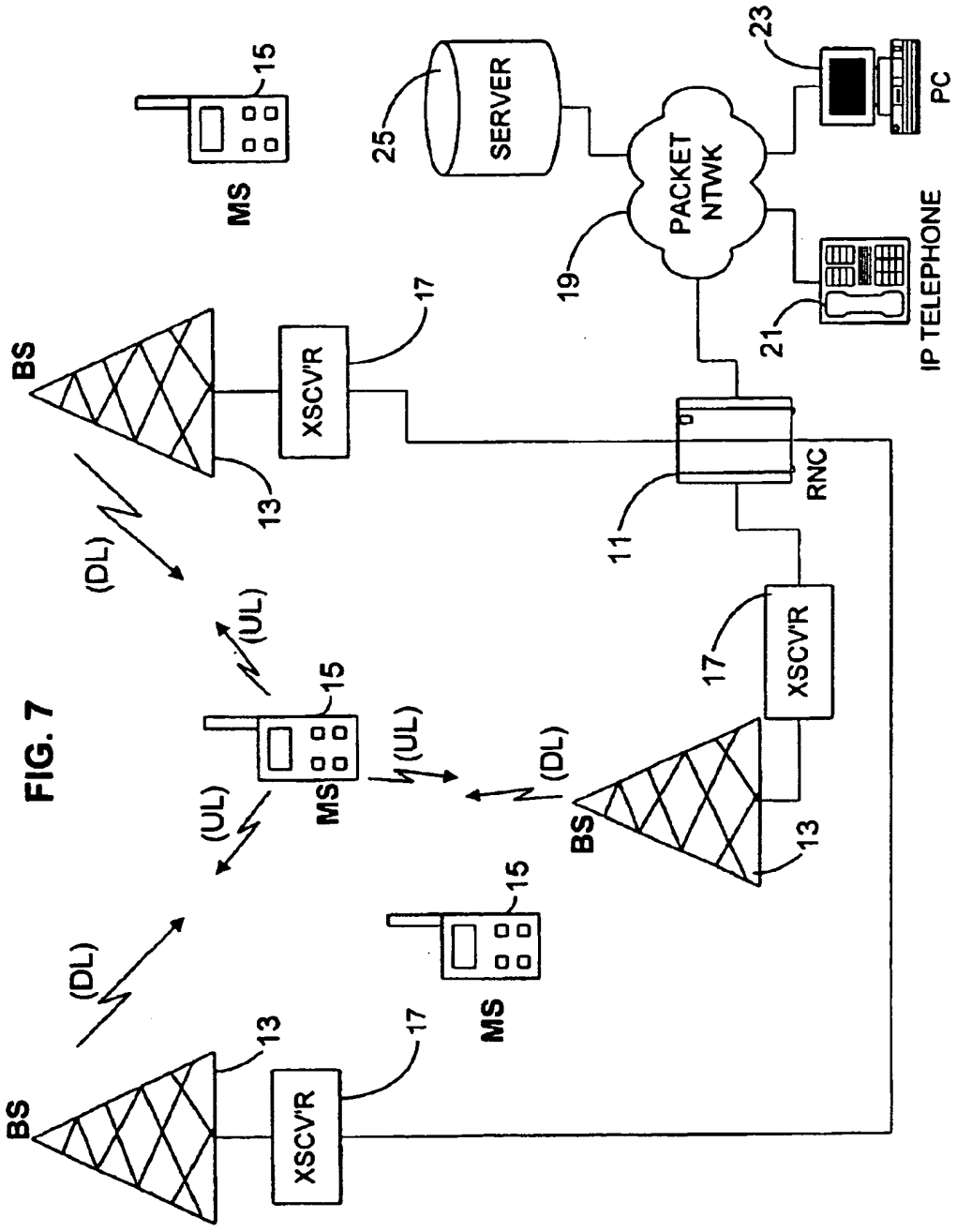
SERVER
25
PACKET NTWK
19
PC
23
IP TELEPHONE
21
RNC
11
XSCV'R
17
BS
13
MS
15
(DL)
(UL)

FIG. 7

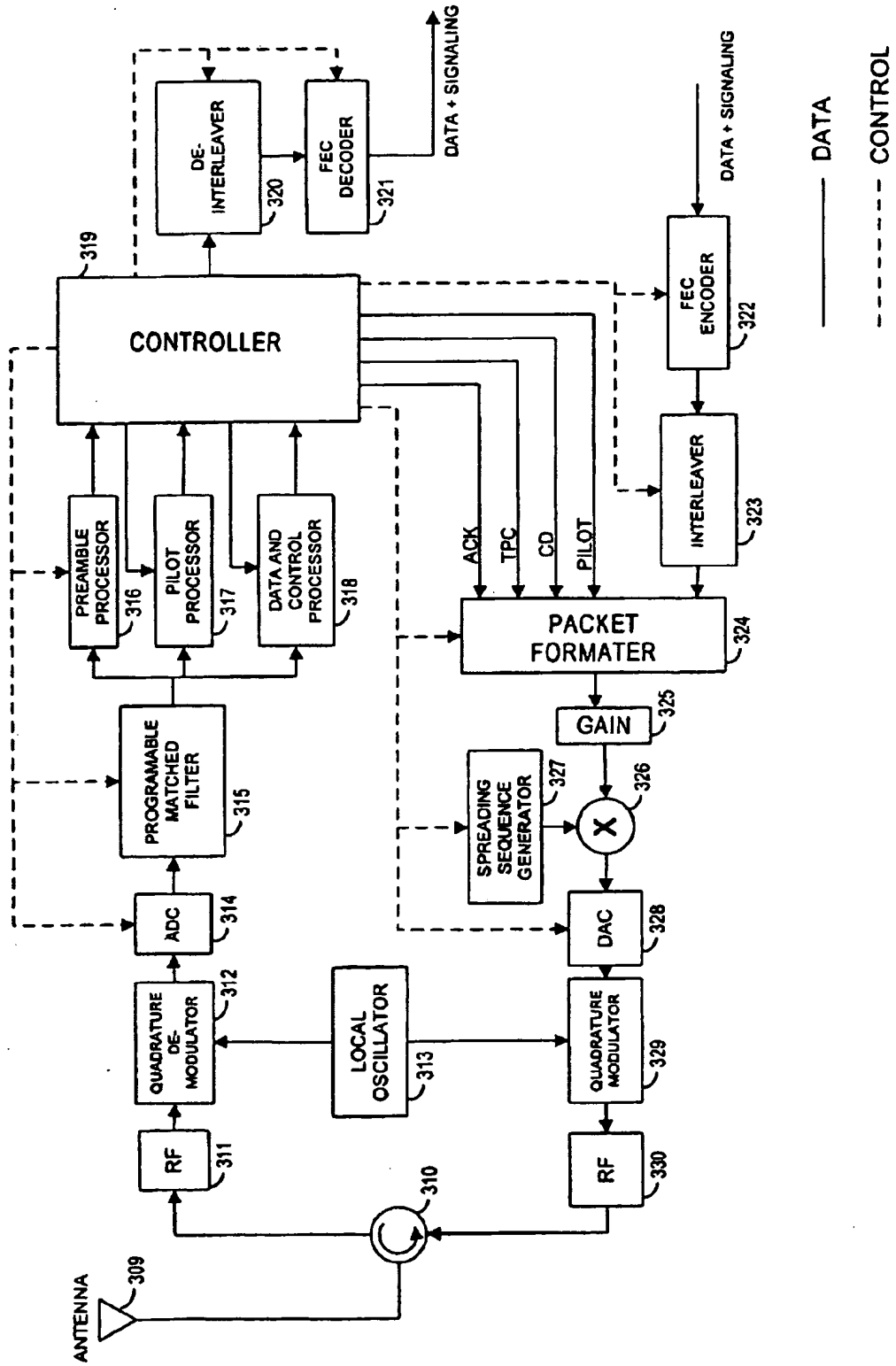
DATA
CONTROL
DATA + SIGNALING
DE-INTERLEAVER
320
FEC DECODER
321
DATA + SIGNALING
319
CONTROLLER
FEC ENCODER
322
INTERLEAVER
323
PREAMBLE PROCESSOR
316
PILOT PROCESSOR
317
DATA AND CONTROL PROCESSOR
318
ACK
TPC
CD
PILOT
PACKET FORMATER
324
GAIN
325
PROGRAMABLE MATCHED FILTER
315
SPREADING SEQUENCE GENERATOR
327
326
ADC
314
DAC
328
QUADRATURE DE-MODULATOR
312
LOCAL OSCILLATOR
313
QUADRATURE MODULATOR
329
RF
311
RF
330
310
ANTENNA
309

FIG. 8

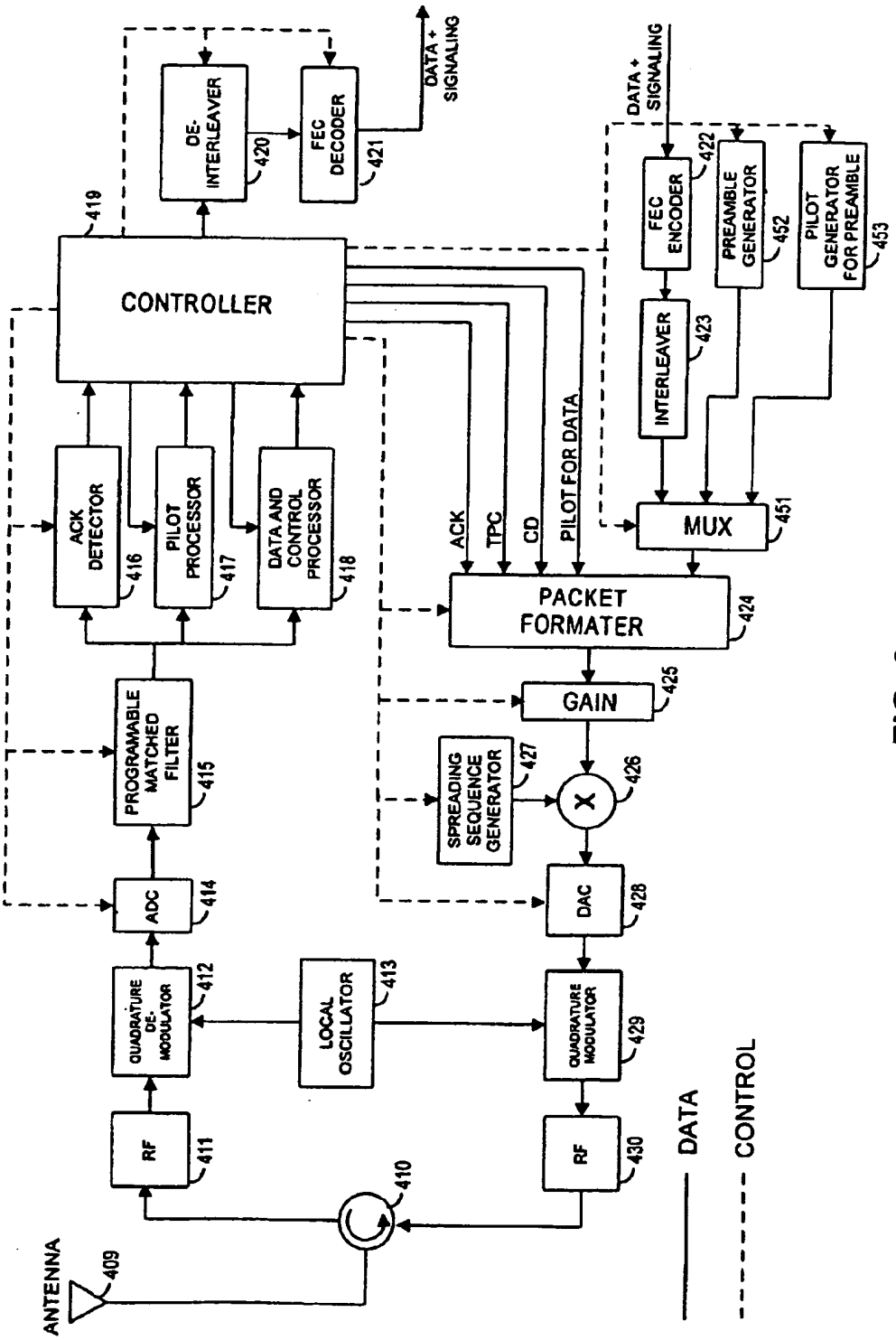
CONTROLLER
419
DE-INTERLEAVER
420
FEC DECODER
421
DATA + SIGNALING
FEC ENCODER
422
PREAMBLE GENERATOR
452
PILOT GENERATOR FOR PREAMBLE
453
INTERLEAVER
423
MUX
451
ACK DETECTOR
416
PILOT PROCESSOR
417
DATA AND CONTROL PROCESSOR
418
ACK
TPC
CD
PILOT FOR DATA
PACKET FORMATER
424
GAIN
425
PROGRAMABLE MATCHED FILTER
415
SPREADING SEQUENCE GENERATOR
427
X
426
ADC
414
DAC
428
QUADRATURE DE-MODULATOR
412
LOCAL OSCILLATOR
413
QUADRATURE MODULATOR
429
RF
411
RF
430
410
ANTENNA
409
DATA
CONTROL

FIG. 9

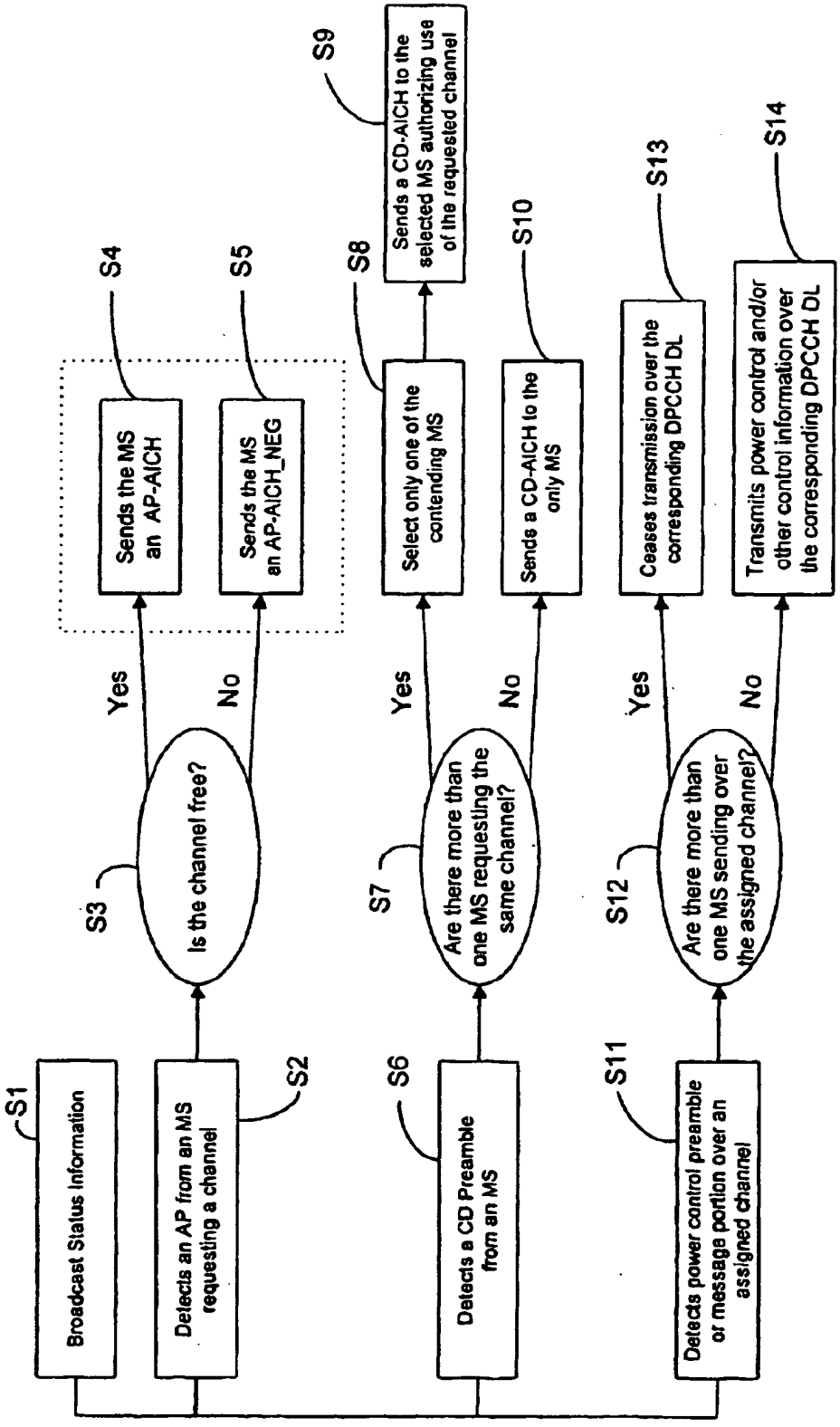
Broadcast Status Information
S1
Detects an AP from an MS requesting a channel
S2
Is the channel free?
S3
Yes
No
Sends the MS an AP-AICH
S4
Sends the MS an AP-AICH_NEG
S5
Detects a CD Preamble from an MS
S6
Are there more than one MS requesting the same channel?
S7
Yes
No
Select only one of the contending MS
S8
Sends a CD-AICH to the selected MS authorizing use of the requested channel
S9
Sends a CD-AICH to the only MS
S10
Detects power control preamble or message portion over an assigned channel
S11
Are there more than one MS sending over the assigned channel?
S12
Yes
No
Ceases transmission over the corresponding DPCCH DL
S13
Transmits power control and/or other control information over the corresponding DPCCH DL
S14

FIG. 10

HYBRID DSMA/CDMA (DIGITAL SENSE MULTIPLE ACCESS/CODE DIVISION MULTIPLE ACCESS) METHOD WITH COLLISION RESOLUTION FOR PACKET COMMUNICATIONS

RELATED APPLICATION

This application claims the benefit of U.S. Provisional Application No. 60/161,443, entitled "HYBRID DSMA/CDMA (DIGITAL SENSE MULTIPLE ACCESS/CODE DIVISION MULTIPLE ACCESS) METHOD WITH COLLISION RESOLUTION FOR PACKET COMMUNICATIONS" filed on Oct. 26, 1999, the disclosure of which is entirely incorporated herein by reference.

FIELD OF THE INVENTION

This invention relates to spread-spectrum communications, and more particularly to code-division-multiple-access (CDMA) cellular, packet-switched communication systems. The inventive concepts involve optimization of packet data communications using a hybrid DSMA-CR/CDMA multiple access method with collision resolution.

BACKGROUND

Recent developments in wireless communications technologies have allowed expansion of service offerings from the original voice telephone service model to include a number of services supporting packet data communications. As customers become increasingly familiar with data services offered through landline networks, they are increasingly demanding comparable data communications in the wireless domain, for example to maintain service while mobile subscribers roam freely or to provide remote service in locations where wireless loops are preferable to landline subscriber loops. A number of technologies support packet data communications in the wireless domain.

For example, a common-packet channel (CPCH) is an uplink transport channel for transmitting variable size packets from a mobile station (MS) to a base station (BS) without the need for direct resource allocation. The channel resource allocation is contention based. A number of mobile stations could at any time content for the same resources, as found in ALOHA systems. The basic CPCH packet data communication does not address issues such as assignment of the channel resources to various base stations, broadcasting channel status and data rates by the base stations and piggy-backing. If a mobile station cannot access one channel, because the channel is busy, it tries another channel, and so on until it finds and accesses an available channel. When many users are trying to access a limited number of channels, the failed access attempts alone can impose a substantial load and even possibly overload one or more channels of the system.

In a Digital Sense Multiple Access (DSMA) system, whenever a base station detects the presence of a subscriber unit transmission on the reverse channel it asserts a periodically occurring flag, called a "busy/idle" flag, on the associated forward channel. This flag is asserted logically true whenever the channel is busy. Any subscriber unit that already is transmitting when the busy/idle flag is set true may continue to transmit. However, all other subscriber units desiring access to a channel must wait until the busy/idle flag is reset or cleared indicating that at least one channel is idle and available. Since the two-way propagation delay is much less than the minimum packet length, the DSMA type protocols perform much better than traditional slotted ALOHA type protocols. The physical layer and the underlying spread spectrum system allow the quick detection of a collision. This approach only allows the base station to generally throttle back the traffic flow. Essentially, each of the mobile stations will interpret a busy state as an instruction to "backoff" and delay its next access attempt. Although this control from the base station helps to prevent overload, it does not work well when there are multiple CPCH channels. The mobile station(s) cannot determine the busy or idle status of multiple channels from a single busy/idle flag signal.

SUMMARY OF THE INVENTION

This invention introduces a hybrid DSMA-CR/CDMA method and apparatus, which addresses the above issues, thus accommodating bursty packet data traffic in an optimum manner. The hybrid DSMA-CR/CDMA method provides a proactive approach to avoid collision by having the base station broadcast the availability and available data rates for each of its channels or for each group of its channels. The mobile station can use the broadcast information to select an idle channel with sufficient data rate before its transmission, instead of waiting for the base station to resolve the collision, if any, in later procedures. The method also allows priority schemes.

Hence a general objective of the invention is to allow mobile stations to assess the availability of packet channel resources.

Another objective relates to efficiently assigning limited channel resources to various base stations.

A further objective is to allow the mobile units to efficiently utilize the acquired channel by continuously transmitting additional packets, which have been passed on from higher layers during transmission.

The present invention provides an improvement to a code-division-multiple-access (CDMA) system employing spread-spectrum modulation. The CDMA system has a radio network controller (RNC) and a plurality of base stations, which serve a plurality of mobile or remote stations. Each base station has a BS-spread-spectrum transmitter and a BS-spread- spectrum receiver. Each of the mobile stations has an MS-spread-spectrum transmitter and an MS-spread-spectrum receiver. In the preferred embodiment, the RNC monitors traffic demand, based on traffic measurement information of communications through the base stations for the mobile stations. Based on the traffic demand or a projection thereof, the RNC assigns channel resources to the base stations, by re-configuring the channel resources within each cell.

At a base station, the inventive method involves broadcasting, on a periodic or non- periodic basis, availability related status information of one or more of the channels allocated to the base station. For example, the status information can contain actual availability information, i.e. idle or busy, or available data rate information, or both. At a mobile station, the steps include monitoring the broadcast(s) of the status information. Based on the broadcast status information, the mobile station selects an idle channel. The channel selection by the mobile station can utilize a dynamic persistence algorithm or any other algorithm commonly known in the art.

Following channel selection, the mobile station starts transmission of a series of access preambles. Each preamble contains a signature selected from a set of predefined

signatures used for communications with the base station. Typically, the preamble signature corresponds to the spreading code and/or the scrambling code used by the network to define the selected logical channel at the physical layer of the CDMA network. The mobile station transmits the preambles, at well-selected time intervals and at increasing power levels. The mobile station stops its transmission of the access preambles when the access preamble has been picked up and detected by the base station, the base station has responded with an acknowledgment AP-AICH, and the mobile station has also successfully received the AP-AICH. Alternatively, the mobile station ceases its access preamble transmissions if the mobile station has transmitted the maximum allowed number of access preambles M_{AP}.

Upon receiving this AP-AICH signal, the mobile station randomly selects a collision detection (CD) signature and transmits a CD preamble containing that signature. This CD preamble procedure is used to prevent interference when more than one MS has received an AP-AICH from the BS. When the base station receives CD preambles, it selects and identifies one preamble. The base station, then transmits a CD acknowledgement channel (CD-AICH) signal corresponding to the CD preamble selected from the received signals. Assuming successful resolution of any overlaps, and selection of the one CD preamble, the base station has effectively assigned the CPCH channel to the one mobile station. Upon receiving a CD acknowledgement CD-AICH, which correspond to the sent CD signature, the mobile station begins to send its packet data along with any closed-loop power control information. The base station also sends its downlink closed-loop power control information simultaneously. A pre-data power control phase is optional.

If the MS detects a loss of the downlink channel, for example, during transmission of the power control preamble or the packet data, the MS halts CPCH uplink transmission. Essentially, the mobile station aborts the access attempt and sends a failure message to the MAC layer of the associated data equipment. The base station can utilize this feature, by cutting off the downlink transmission, to instruct mobile stations not to use a channel following an unresolved collision.

During a transmission of data, the mobile station that has successfully obtained access can piggy-back packets, one after another, so long as it has packets ready to send, up to a maximum limit set by the network. Essentially, this allows the mobile station to hold the CPCH channel if the MAC equipment supplies further packets to the PHY elements in the midst of an uplink transmission.

Additional objects, advantages and novel features of the invention will be set forth in part in the description which follows, and in part will become apparent to those skilled in the art upon examination of the following and the accompanying drawings or may be learned by practice of the invention. The objects and advantages of the invention may be realized and attained by means of the instrumentalities and combinations particularly pointed out in the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

The drawing figures depict preferred embodiments of the present invention by way of example, not by way of limitations. In the figures, like reference numerals refer to the same or similar elements.

FIG. 1 is an illustration of the frame structure of a CPCH status indicator channel (CSICH) used to provide information as to the availability of a plurality of CPCH channels in cord with the present invention.

FIG. 2 is an illustration of the relationship of a number of CPCH channels to the CSICH channel.

FIG. 3 is an illustration of the structure of the CPCH random access transmission.

FIG. 4 is an illustration of the timing of PCPCH and AICH transmission as seen by the UE, with T_{CPCH}=0.

FIG. 5 is a signal diagram of a DSMA transmission.

FIG. 6 is a diagram of the packet timing of a number of user CPCH transmissions.

FIG. 7 is a functional block diagram of a CDMA network, capable of implementing the communications in accord with the present invention.

FIG. 8 is a functional block diagram of a spread spectrum base station for use in a network of the type shown in FIG. 7.

FIG. 9 is a functional block diagram of a spread spectrum remote or mobile station for use in a network of the type shown in FIG. 7.

FIG. 10 a process flow diagram illustrating an example of the base station (BS) Access Procedure.

DETAILED DESCRIPTION OF THE PRESENTLY PREFERRED EMBODIMENTS

Reference now is made in detail to the presently preferred embodiments of the invention, examples of which are illustrated in the accompanying drawings, wherein like reference numerals indicate like elements throughout the several views.

The present invention involves a hybrid DSMA-CR/CDMA methodology for selecting and accessing one of a number of communication channels in a spread spectrum wireless communication network. The inventive access methodology accommodates bursty traffic in an optimum manner. The hybrid DSMA-CR/CDMA method provides a proactive approach to avoid collision by having the base station broadcast the availability and available data rates for each channel or group of its channels.

The broadcast of the CPCH channel-availability information preferably uses a common channel, referred to herein as a CPCH status indicator channel (CSICH). FIG. 1 shows an example of the frame structure of a CSICH channel. The CSICH channel is a fixed rate (SF=256) physical channel used to carry CPCH status information. Although the inventive concepts encompass other forms of channelization, a CSICH is typically associated with a physical channel used for transmission of CPCH AP-AICH and uses the same channelization and scrambling codes. FIG. 2 provides a logical diagram of the CSICH, as well as the downlink (DL) and uplink (UL) CPCH channels used through one exemplary base station. Each uplink (UL) channel is associated with a downlink (DL) channel, to form a channel pair for associated two-way packet data communications between a mobile station and the base station. The drawing shows four such pairs of UL and DL channels, although the network may allocate fewer channels or more channels to any particular base station.

The mobile station uses the broadcast information in the CSICH to select an idle CPCH channel with sufficient data rate before initiating its upstream transmission. The mobile station attempts to seize the selected uplink (UL) channel and waits for an acknowledgement over the associated downlink (DL) channel. To appreciate the hybrid methodology, it may be helpful to first recap the basic functions of CPCH and DSMA.

The basic common-packet channel CPCH is an uplink transport channel for transmitting variable size packets from

a remote or mobile station (MS) to a base station (BS), without the need for direct resource allocation. The channel resource allocation is contention based. A number of mobile stations could at any time contend for the same resources, as in ALOHA systems.

In operation, a MS upon power-up searches for a transmission from any nearby BS. Upon successful synchronization with one or more BSs, the MS receives the necessary system parameters from a continuously transmitted BS broadcast control channel (BCCH), which is broadcast by all base stations. Using the information transmitted from the BCCH, the MS can determine various parameters required when first transmitting to a BS. Parameters of interest are the loading of all the base stations in the vicinity of the MS, their antenna characteristics, spreading codes used to spread the downlink transmitted information, timing information and other control information.

With this information, the remote or mobile station (MS) can transmit specific waveforms in order to capture the attention of a nearby base station (BS). The MS, having all the necessary information from the nearby BS, starts transmitting a particular access preamble from a set of predefined access preambles. FIG. 3 shows the format of a random access CPCH transmission, and FIG. 4 illustrates examples of both the downlink (DL) and uplink (UL) transmissions.

The MS transmits the particular access preamble (AP) at predefined time intervals set according to synchronization information derived from downlink transmitted signals received over a broadcast channel. The MS transmits a set of access preambles of duration T_p whose power is increased in time from preamble transmission to preamble transmission, preferably in a step-wise manner (see P_0 to P_3 in FIG. 3). The transmitted power during each access preamble transmission is constant. The transmission of the access preambles ceases when: (1) the access preamble has been picked up, detected, by the BS, and the BS has responded to the MS with an acknowledgment AP-AICH which MS has also successfully received; or (2) the MS has transmitted the maximum allowed number of access preambles M_{AP}.

With this ALOHA type access technique, there is a good possibility that two or more MSs may try to access the BS using the same access preamble at substantially the same time. In such a case, the AP-AICH acknowledgement signal could be successfully received by more than one MSs. If these MSs are allowed to transmit data, the transmissions will collide. In case of collision, none of the data from either of the transmitting MSs will be received correctly. To resolve this problem, the MSs need to undergo a collision detection or "CD" phase.

In the CD phase, upon receiving an AP-AICH acknowledgement, the MS randomly selects a collision detection (CD) signature from a predetermined set of possible CD signatures, and transmits a CD preamble containing the coded CD signature (shown as with cross-hatch shading at PI on the UL channel in FIG. 4). If the base station successfully receives a CD preamble, it sends back a CD acknowledgement (CD-AICH), which is the same as or otherwise corresponds to the CD signature transmitted by the MS. The BS responds to only one of the many possible received CD preambles transmitted by different MSs. Upon receiving a CD-AICH corresponding to its own CD preamble signature, indicating that there we no collisions, the MS will begin to send its packet data along with any closed-loop power control information (FIG. 4). The BS will also send its downlink closed-loop power control information simultaneously (FIG. 4). Since the CD preamble signatures are chosen at random from the set of available signatures, it is very likely that different MSs will chose different CD preamble signatures. Any mobile station MS that does not receive a corresponding to its CD preamble CD-AICH signal, aborts its access attempt. This CD preamble procedure is used to prevent interference when two or more MSs have received a valid AP-AICH from the BS at the same time.

A Physical Common Packet Channel (PCPCH) is used to carry the logical CPCH. The CPCH transmission is based on DSMA-CD approach with fast acquisition indication. The MS can start transmission at a number of well-defined time-offsets, relative to the frame boundary of the received broadcast channel (BCH) of the current cell. The structure of the CPCH random access transmission is shown in FIG. 3. By means of an example, the CPCH random access transmission consists of one or several Access Preambles (AP) of length 4,096 chips, one Collision Detection Preamble (CD-P) of length 4,096 chips, 0 to 8 slots of a DPCCH Power Control Preamble (PC-P) and a message of variable length N times 10 msec.

The scrambling code of the Access Preamble and the CD preamble could be chosen to be a code segment of the Gold code. The message part carries the actual data and control information. The message is divided into 10 msec frames. N_{MF} is a higher layer parameter. Each 10 msec frame is split into 15 slots, each of length T_{slot}=2,560 chips. Each slot consists of two parts, a data part that carries higher layer information and a control part that carries Layer 1 control information. The data and control parts are transmitted in parallel via I/Q multiplexing.

The data part consists of $10*2^k$ bits, where k=0, 1, 2, 3, 4, 5, 6, corresponding to spreading factors of 256, 128, 64, 32, 16, 8, 4 respectively. Various rates can be mapped to different signature sequences.

The spreading factor for the UL-DPCCH (message control part) is 256. CPCH can operate in all rates as shown above.

FIG. 4 illustrates the PCPCH/AICH timing relationship when T_{CPCH} is set to 0 and all access slot subchannels are available for PCPCH. The T_{CPCH} timing parameter determines the default access slot spacing between successive preambles and the response time of the base station to these preambles. When T_{CPCH} is set to zero or one, the following PCPCH/AICH timing values apply:

Note that a1 corresponds to AP-AICH and a2 corresponds to CD-AICH.

π_{p-p}=Time to next available access slot, between Access Preambles.
Minimum time=15,360 chips+5,120 chips×T_{CPCH}
Maximum time=5,120 chips×12=61,440 chips
Actual time is time to next slot (which meets minimum time criterion) in allocated access slot subchannel group.

π_{p-a1}=Time between Access Preamble and AP-AICH has two alternative values: 7,680 chips or 12,800 chips, depending on T_{CPCH}

π_{a1-cdp}=Time between receipt of AP-AICH and transmission of the CD Preamble has one value: 7,680 chips.

π_{p-cdp}=Time between the last AP and CD Preamble is either 3 or 4 access slots, depending on T_{CPCH}

π_{cdp-a2}=Time between the CD Preamble and the CD-AICH has two alternative values: 7,680 chips or 12,800 chips, depending on T_{CPCH}

$\pi_{cdp-pcp}$=Time between CD Preamble and the start of the Power Control Preamble is either 3 or 4 access slots, depending on T_{CPCH}

The downlink control channel, DPCCH, contains fields comprising Pilot, FBI and TPC bits. Table 1 defines the DPCCH fields, which only include Pilot, FBI and TPC bits.

TABLE 1

DPCCH fields for CPCH power control preamble segment.

Slot Format #1	Channel Bit Rate (kbps)	Channel Symbol Rate (ksps)	SF	Bits/ Frame	Bits/ Slot	N_{pilot}	N_{TFCI}	N_{FBI}	N_{TPC}
0	15	15	256	150	10	8	0	0	2
1	15	15	256	150	10	7	0	1	2

In accordance with Digital Sense Multiple Access (DSMA) approach, whenever a BS detects the presence of a subscriber unit transmission on the reverse or UL channel it asserts a periodically occurring flag, called a "busy/idle" flag, on the associated forward or DL channel. This flag is asserted logically true whenever the channel is busy. Any subscriber unit that already is transmitting when the busy/idle flag is set true may continue to transmit. However, all other subscriber units desiring access to a channel must wait for some predetermined period or until the busy/idle flag is reset or cleared indicating that at least one channel is idle and available. Since the two-way propagation delay is much less than the minimum packet length, the DSMA type protocols perform much better as compared to traditional slotted ALOHA type protocols. The physical layer and the underlying spread spectrum system allow the quick detection of the collision. In case of collision, the capture effect might lead to collision resolution, which increases the throughput efficiency.

The Packet Radio System can be modeled as an M/M/1 Queue since the packet arrival process is Poisson and the packet length distribution is assumed to be exponential. In "Analytical model of Busy Channel Multiple Access for Packet Radio in a local environment, Oreste Andrisano, et al, IEEE Transaction on Vehicular Technology, November 1990", the authors have used this model for the analysis of a Busy Channel Multiple Access Protocol. The authors showed throughput of up to 0.6 with delay of only a few slots., Such results can function as a lower bound for performance of the current invention. In the current DSMA-CR/CDMA method, there is a collision detection and resolution capability and there is room for priority schemes. The false digital sensing probability in the current proposal can be reduced to a very low number by allocation of the necessary power to the Free and Busy signals in the access method.

FIG. **5** illustrates the operation of the DSMA-like protocol with CLPC. The Collision feedback delay cycle approaches zero and represents a small fraction of the packet length. The minimum packet length is 10 msec in this system. The top line represents the transmissions from the base station (BS) over the downlink (DL) channel. The bottom line represents the transmissions from the mobile station (MS) over the CPCH uplink (UL) channel. As can be seen in FIG. 5, the availability-or-non-availability of the CPCH channel is periodically broadcast in the associated downlink, where the F signal from the BS represents an indication that the channel is free, and the B signal from the BS represents an indication that the channel is busy.

The key issue in having a high throughput and low delay with this DSMA method is the periodic or non-periodic transmission of idle (F) and busy (B) indications of the CPCH channel. This periodicity could remain constant or it could vary. The broadcast information could be busy and free indications or only free indication. The different user devices MS seize the channel when idle, for transmission of one or more packets.

HYBRID DSMA/CDMA METHOD WITH COLLISION RESOLUTION

The present invention is a hybrid DSMA/CDMA method and apparatus with collision resolution for spread spectrum communication. FIG. **6** represents the general environment of the packet generation and thus the demand for channel access in a multi-channel CDMA packet data network. The simplified illustration represents users i to n (four shown), wherein the associated data equipment generates packets for transmission at relatively random times. The MAC or media access control layer devices supply these packets to the PHY or physical layer elements for transmission over the CDMA network. As shown in the simplified example of FIG. **2**, a base station (BS) provides a plurality of channel pairs. The PHY or physical layer elements must communicate with the base station to select and obtain access to an available uplink (UL) channel for transmission of the packets. Where there are sufficient channel resources for all active users, all user devices may transmit over the channels, essentially in parallel. However, during these transmissions there often are other User Equipment (UE) awaiting access to a channel.

In a preferred embodiment (FIG. **7**), the CDMA system comprises a radio network controller (RNC) **11**, a plurality of base stations **13** and a plurality of mobile stations **15**. Each base station (BS) **13** has BS-spread-spectrum transmitter and a BS-spread-spectrum receiver, shown as a single transceiver (XSCV'R) system **17** for simplicity in this drawing. Each of the mobile stations (MS) **15** has an MS-spread-spectrum transmitter and an MS-spread-spectrum receiver (not separately shown). Exemplary transmitters and receivers for use in the BS and MS network elements are discussed in more detail below with regard to FIGS. **8** and **9**. In a typical embodiment, the radio network controller (RNC) **11** provides two-way packet data communications to a wide area network, shown by way of example as a packet-switched network **19**. The RNC **11** and the network **19** provide the MS units **15** with two-way packet data communications services to enable communication to and from devices, represented by way of example by the IP telephone **21**, the personal computer (PC) **23** and the server **25**.

The CDMA system provides a number of logically different channels for upstream and downstream communications over the air-link interface (see e.g. FIG. **2**). Each channel is defined by one or more of the codes, for example the spreading code and/or the scrambling code. Several of the channels are common channels, but most of the channels are used for uplink or downlink packet communications between the base stations **13** and the mobile stations **15**.

The RNC **11** measures traffic through the base stations **13** going to and from the mobile stations **15**. In this way, the

radio network controller (RNC) 11 monitors traffic demand in the illustrated network. The RNC **11** assigns channel resources to the base stations **13**, by re-configuring configuring the channel resources (channelization codes) within each cell of each base station **13**. Each base station **13** maintains current status information, e.g. availability and/or available data rate, for each assigned channel and broadcasts that information in one of the common channels used by the base station.

According to the present invention, the spread-spectrum transmitter in the base station transceiver **17** broadcasts the status information to the mobile stations **15** on a periodic or non- periodic basis. This transmission utilizes one of the common downlink channels, which is referred to here as a CPCH status indicator channel (CSICH). This broadcast status information can relate the availability (Idle) or non-availability (Busy) of every single Common Packet Channel or the availability or non-availability of groups of Common Packet Channels. The broadcast status information may also indicate the available data rates for every single Common Packet Channel or for groups of Common Packet Channels.

The CPCH Status Indicator Channel (CSICH) is a fixed rate (SF=256) physical channel used to carry CPCH status information. In the preferred embodiment of FIG. 1, the CSICH is associated with a physical channel used for transmission of CPCH-AP-AICH and uses the same channelization and scrambling codes. The illustrated CSICH frame consists of 15 consecutive access slots (AS) each of length 40 bits. Each access slot consists of two parts, a part of duration 4096 chips with no transmission that is not formally part of the CSICH, and a Status Indicator (SI) part consisting of 8 bits $b_{8i}, \ldots b_{8i+7}$, where i is the access slot number. The part of the access slot with no transmission is reserved for use by AICH, AP-AICH or CD/CA-ICH. The modulation used by the CSICH is the same as for the PICH. The phase reference for the CSICH is the Primary CPICH.

The Status Indicators are in all the access slots of the CSICH frame, even if some signatures and/or access slots are shared between CPCH and random access channel (RACH) services. Each CSICH frame carriers N Status Indicators. The mapping from $\{SI_0, \ldots, SI_{N-1}\}$ to the CSICH bits $\{b_0, \ldots, b_{119}\}$ follows the rules set forth in table 1.

TABLE 1

Mapping of Status Indicators (SI) to CSICH bits

Number of SI per frame (N)	$SI_n = 1$	$SI_n = 0$
N = 1	$\{b_0, \ldots, b^{119}\} = \{-1, -1, \ldots, -1\}$	$\{b_0, \ldots, b_{119}\} = \{+1, +1, \ldots, +1\}$
N = 3	$\{b_{40n}, \ldots, b_{40n+39}\} = \{-1, -1, \ldots, -1\}$	$\{b_{40n}, \ldots, b_{40n+39}\} = \{+1, +1, \ldots, +1\}$
N = 5	$\{b_{24n}, \ldots, b_{24n+23}\} = \{-1, -1, \ldots, -1\}$	$\{b_{24n}, \ldots, b_{24n+23}\} = \{+1, +1, \ldots, +1\}$
N = 15	$\{b_{8n}, \ldots, b_{8n+7}\} = \{-1, -1, \ldots, -1\}$	$\{b_{8n}, \ldots, b_{8n+7}\} = \{+1, +1, \ldots, +1\}$
N = 30	$\{b_{4n}, \ldots, b_{4n+3}\} = \{-1, -1, -1, -1\}$	$\{b_{4n}, \ldots, b_{4n+3}\} = \{+1, +1, +1, +1\}$
N = 60	$\{b_{2n}, b_{2n+1}\} = \{-1, -1\}$	$\{b_{2n}, b_{2n+1}\} = \{+1, +1\}$

A variety of different availability-status bit mapping arrangements may be used. Higher layers set the values of the Status Indicators. At the user equipment (UE) the number of status indicators per frame is a higher layer parameter. The higher layers provide layer 1 or PHY equipment with the mapping between the values of the Status Indicators and the actual availability of the CPCH resources.

In operation of the network of FIG. **7**, a mobile station (MS) **15** monitors the broadcast information on the CSICH channel. When the particular MS **15** has a first packet to transmit, it uses the latest broadcast information to select an idle CPCH uplink (UL) channel. The selection of UL channel by the MS can be based on a dynamic persistence algorithm or any other algorithm commonly known in the art.

The MS **15** then enters the access phase. The base station (BS) **13** transmits a common synchronization channel. In the access phase, the mobile station (MS) **15** initiates a ramp up process in order to capture the available CPCH channel. The access phase involves the MS spread-spectrum transmitter sending one of more access preambles in access slots defined in relation to a frame timing signal derived from receipt of the common synchronization channel. Each preamble contains a signature selected from a set of predefined signatures at a well-selected time interval in sequentially increasing power levels. The selected signature effectively identifies the selected one of the uplink channels.

The transmission of the access preambles ceases when one access preamble has been picked up and detected by the BS, and the BS has responded with an acknowledgment AP-AICH, which the MS has also successfully received. In the alternative, the mobile station (MS) **15** will cease its transmission of access preambles if the MS has transmitted the maximum allowed number of access preambles M_{AP}.

If multiple MSs are trying to access the BS using the same access preamble signature, more than one mobile station might have succeeded through the first ramp-up phase at about the same time. Each successful mobile station **15** and the base station **13** will then enter a Collision Resolution phase, where the BS effectively assigns the requested CPCH channel to only one of the contending mobile stations. The collision resolution phase is also referred to as the channel assignment phase. In this collision resolution phase, upon receiving this AP-AICH, each successful MS randomly selects a collision detection (CD) signature and transmits a CD preamble. The BS only responds to one of the mobile stations by sending out a CD acknowledgement (CD-AICH), which corresponds to the CD signature of the selected MS. Typically the base station **13** transmits the CD preamble from the selected mobile station back over the corresponding downlink channel. However, another code could be used as the base station CD preamble signature in the CD-AICH signal, so long as it is known to correspond to the mobile station CD preamble.

Upon receiving this corresponding CD-AICH, the selected MS enters the data transmission phase and begins to send its packet data along with any closed loop power control information. The BS also sends its downlink closed-loop power control information simultaneously. During the data transmission phase, if the PHY elements of the MS receive more packets in the interim, they will transmit the additional packet while the MS remains in control of its CPCH channel.

An optional pre-data power phase can be carried out before the data transmission phase after the MS receives the CD-AICH.

Any mobile station **15** that transmitted a CD preamble but failed to receive a corresponding acknowledgement CD-AICH with refrain from further transmissions on the CPCH channel. In this example, the collision has been resolved in the CD phase, and the base station **13** has allocated the CPCH channel to only one mobile station **15**.

In case of an unresolved collision, two or more mobile stations will enter the pre-data power control phase or the

message phase. Upon detection of such a condition, the BS will force the colliding mobile stations to abort their data transmissions by ceasing the transmission of the corresponding Downlink Dedicated channel DL-DPCCH. Upon detecting the loss of the DL-DPCCH transmission, each MS will abort its uplink transmission.

Another facet of this invention is introduction of channel resource assignment. The CPCH resources are assigned to the Base Node by the Radio Network Controller (RNC) based on the traffic demand projection. The RNC re-configures the CPCH set within a cell based on traffic measurement information that it receives from the Base Node and mobile stations. The channel resource assignment is optional.

There could be multiple CPCH channels and they could operate at various data rates. The flexibility to operate the CPCH at various rates allows the operator to match the incoming packet size distribution to the possible payload size in each CPCH data rate.

For each CPCH physical channel in a CPCH set allocated to a cell the following physical layer parameters are included in the System Information message:

Uplink (UL) Access Preamble (AP) scrambling code(s).

UL Access Preamble signature set

The Access preamble slot sub-channels group

AP-AICH preamble channelization code(s).

UL Collision Detection (CD) preamble scrambling code(s).

CD Preamble signature set

CD preamble slot sub-channels group

CD-AICH preamble channelization code(s).

CPCH UL scrambling code(s).

CPCH UL channelization code (variable, data rate dependant).

DPCCH Downlink (DL) channelization code(s) (512 chip)

The following are access, collision detection/resolution and CPCH data transmission parameters:

Power ramp-up, Access and Timing parameters (Physical layer parameters)

1) M_{AP}=Maximum number of allowed consecutive access attempts (retransmitted preambles) if there is no AP-AICH response.

2) PCPCH=Initial open loop power level for the first CPCH access preamble sent by the MS.

3) ΔP_0=Power step size for each successive CPCH access preamble.

4) ΔP_1=Power step size for each successive CPCH access preamble in case of negative AICH. A timer is set upon receipt of a negative AICH. This timer is used to determine the period after receipt of a negative AICH when ΔP_1 is used in place of ΔP_0.

5) T_{CPCH}=CPCH transmission timing parameter

To ensure a complete understanding of the invention, it may be helpful to consider the structure of preferred embodiments of the base station transceivers and the mobile station transceivers.

FIG. **8** illustrates a presently preferred embodiment of a BS spread-spectrum transmitter and a BS spread-spectrum receiver, essentially in the form of a base-band processor for performing the PHY layer functions. The BS spread-spectrum transmitter and the BS spread-spectrum receiver form one of the transceivers **17** at a base station **13**. The BS spread-spectrum receiver includes an antenna **309** coupled to a circulator **310**, a receiver radio frequency (RF) section **311**, a local oscillator **313**, a quadrature demodulator **312**, and an analog-to-digital converter **314**. The receiver RF section **311** is coupled between the circulator **310** and the quadrature demodulator **312**. The quadrature demodulator is coupled to the local oscillator **313** and to the analog to digital converter **314**. The output of the analog-to-digital converter **315** is coupled to a programmable-matched filter **315**.

A preamble processor **316**, pilot processor **317** and data-and-control processor **318** are coupled to the programmable-matched filter **315**. A controller **319** is coupled to the preamble processor **316**, pilot processor **317** and data-and-control processor **318**. A de-interleaver **320** is coupled between the controller **319** and a forward-error-correction (FEC) decoder **321**. The decoder **321** outputs data and signaling received via the UL channel to the MAC layer elements (not shown).

The BS spread-spectrum transmitter includes a forward-error-correction (FEC) encoder **322** coupled to an interleaver **323**. A packet formatter **324** is coupled to the interleaver **323** and to the controller **319**. A variable gain device **325** is coupled between the packet formatter **324** and a product device **326**. A spreading-sequence generator **327** is coupled to the product device **326**. A digital-to-analog converter **328** is coupled between the product device **328** and quadrature modulator **329**. The quadrature modulator **329** is coupled to the local oscillator **313** and a transmitter RF section **330**. The transmitter RF section **330** is coupled to the circulator **310**.

The controller **319** has control links coupled to the analog-to-digital converter **314**, the programmable-matched filter **315**, the preamble processor **316**, the digital-to-analog converter **328**, the spreading sequence generator **327**, the variable gain device **325**, the packet formatter **324**, the de-interleaver **320**, the FEC decoder **321**, the interleaver **323** and the FEC encoder **322**.

A received spread-spectrum signal from antenna **309** passes through circulator **310** and is amplified and filtered by the receiver RF section **311**. The local oscillator **313** generates a local signal, which the quadrature demodulator **312** uses to demodulate in-phase and quadrature phase components of the received spread-spectrum signal. The analog-to-digital converter **314** converts the in-phase component and the quadrature-phase component to digital signals. These functions are well known in the art, and variations to this block diagram can accomplish the same functions.

The programmable-matched filter **315** despreads the received spread-spectrum signal components. A correlator, as an alternative, may be used as an equivalent means for despreading the received spread-spectrum signal.

The preamble processor **316** detects the preamble portion of the received spread-spectrum signal. The pilot processor **317** detects and synchronizes to the pilot portion of the received spread-spectrum signal. The data and control processor **318** detects and processes the data portion of the received spread-spectrum signal. Detected data passes through the controller **319** to the de-interleaver **320** and FEC decoder **321**. Data and signaling from the UL are outputted from the FEC decoder **321** to the higher layer elements in or associated with the BS **13**.

In the BS transceiver, the MAC layer elements supply data and signaling information, intended for DL transmission, to the input of the FEC encoder **322**. The signaling and data are FEC encoded by FEC encoder **322**, and interleaved by interleaver **323**. The packet formatter **324** formats data, signaling, acknowledgment signal, collision detection signal, pilot signal and transmitting power control

(TPC) signal into appropriate packets. Each packet is outputted from the packet formatter **324**, and the packet level is amplified or attenuated by variable gain device **325**. The packet is spread-spectrum processed by product device **326**, with a spreading chip-sequence from spreading-sequence generator **327**. The packet is converted to an analog signal by digital-to-analog converter **328**, and in-phase and quadrature-phase components are generated by quadrature modulator **329** using a signal from local oscillator **313**. The modulated DL packet is translated to a carrier frequency, filtered and amplified by the transmitter RF section **330**, and then it passes through the circulator **310** and is radiated by antenna **309**.

FIG. **9** shows an embodiment of an MS spread-spectrum transmitter and an MS spread-spectrum receiver, essentially in the form of a base-band processor for performing the PHY layer transceiver functions. The MS spread-spectrum transmitter and the MS spread-spectrum receiver are located at the remote or mobile station (MS) **15**, shown in FIG. **7**. The MS spread-spectrum receiver includes an antenna **409** coupled to a circulator **410**, a receiver radio frequency (RF) section **411**, a local oscillator **413**, a quadrature demodulator **412**, and an analog-to-digital converter **414**. The receiver RF section **411** is coupled between the circulator **410** and the quadrature demodulator **412**. The quadrature demodulator is coupled to the local oscillator **413** and to the analog to digital converter **414**. The output of the analog-to-digital converter **415** is coupled to a programmable-matched filter **415**.

An acknowledgment detector **416**, pilot processor **417** and data-and-control processor **418** are coupled to the programmable-matched filter **415**. A controller **419** is coupled to the acknowledgment detector **416**, pilot processor **417** and data-and-control processor **418**. A de-interleaver **420** is coupled between the controller **419** and a forward-error-correction (FEC) decoder **421**. The decoder **421** outputs data and signaling received via the DL channel to the MAC layer elements (not shown) of the MS.

The MS spread-spectrum transmitter includes a forward-error-correction (FEC) encoder **422** coupled to an interleaver **423**. A packet formatter **424** is coupled through a multiplexer **451** to the interleaver **423**. The packet formatter **424** also is coupled to the controller **419**. A preamble generator **452** and a pilot generator **453** for the preamble are coupled to the multiplexer **451**. A variable gain device **425** is coupled between the packet formatter **424** and a product device **426**. A spreading-sequence generator **427** is coupled to the product device **426**. A digital-to-analog converter **428** is coupled between the product device **428** and quadrature modulator **429**. The quadrature modulator **429** is coupled to the local oscillator **413** and a transmitter RF section **430**. The transmitter RF section **430** is coupled to the circulator **410**.

The controller **419** has control links coupled to the analog-to-digital converter **414**, the programmable-matched filter **415**, the acknowledgment detector **416**, the digital-to-analog converter **428**, the spreading sequence generator **427**, the variable gain device **425**, the packet formatter **424**, the de-interleaver **420**, the FEC decoder **421**, the interleaver **423**, the FEC encoder **422**, the preamble generator **452** and the pilot generator **453**.

A received spread-spectrum signal from antenna **409** passes through circulator **410** and is amplified and filtered by the receiver RF section **411**. The local oscillator **413** generates a local signal, which the quadrature demodulator **412** uses to demodulate in-phase and quadrature phase components of the received spread-spectrum signal. The analog-to-digital converter **414** converts the in-phase component and the quadrature-phase component to digital signals. These functions are well known in the art, and variations to this block diagram can accomplish the same functions.

The programmable-matched filter **415** despreads the received spread-spectrum signal components. A correlator, as an alternative, may be used as an equivalent means for despeading the received spread-spectrum signal.

The acknowledgment detector **416** detects the acknowledgment in the received spread- spectrum signal. The pilot processor **417** detects and synchronizes to the pilot portion of the received spread-spectrum signal. The data and control processor **418** detects and processes the data portion of the received spread-spectrum signal. Detected data passes through the controller **419** to the de-interleaver **420** and FEC decoder **421**. Data and signaling from the DL are outputted from the FEC decoder **421** to the higher level elements in or associated with the MS **15**.

In the MS transceiver, the MAC layer elements supply data and signaling information intended for transmission over the UL channel, to the input of the FEC encoder **422**. Data and signaling information are FEC encoded by FEC encoder **422**, and interleaved by interleaver **423**. The preamble generator **452** generates a preamble, and the pilot generator **453** generates a pilot for the preamble. The multiplexer **451** multiplexes the data, preamble and pilot, and the packet formatter **424** formats the preamble, pilot and data into a common-packet channel packet. Further, the packet formatter **424** formats data, signaling, acknowledgment signal, collision detection signal, pilot signal and TPC signal into a packet. The packet formatter **424** outputs the packet, and the packet level is amplified or attenuated by variable gain device **425**. The packet is spread-spectrum processed by product device **426**, with s spreading chip-sequence from spreading-sequence generator **427**. The packet is converted to an analog signal by digital-to-analog converter **428**, and quadrature modulator **429** using a signal from local oscillator **413** generates in-phase and quadrature-phase components. The modulated UL packet is translated to a carrier frequency, filtered and amplified by the transmitter RF section **430** and then it passes through the circulator **430** and is radiated by the antenna **409**.

Below is an illustration of a physical layer access procedure for the MS:

1) The MS monitors the Status Broadcast information to determine the availability of the CPCH channels.
2) The MS MAC function selects a CPCH transport channel from the channels available in the assigned CPCH set. The CPCH channel selection preferably uses a dynamic persistence algorithm for the selection of the CPCH channel.
3) The MS MAC function builds a transport block set for the next transmission or transport interval (TTI) using transport formats, which are assigned to the logical channel with data to transmit, and sends this transport block set to the MS PHY function for CPCH access and uplink transmission on the selected CPCH transport channel.
4) The MS sets its preamble transmit power to the value P_{CPCH} which is supplied by the MAC layer for initial power level for this CPCH access attempt.
5) The MS sets the AP (access preamble) Retransmission Counter to M_{AP}, the maximum number of allowed consecutive access attempts (retransmitted preambles) if there is no AP-AICH response.
6) The MS randomly selects a CPCH-AP signature from the signature set for this selected CPCH channel.
7) The MS derives the available CPCH-AP access slots in the next two frames, defined by SFN and SFN+1 in the

AP access slot sub-channel group, a sub-channel group is defined as a set of access slots and access preamble signatures. The MS randomly selects one access slot from the available access slots in the next frame, defined by SFN, if there is one available. If there is no access slot available in the next frame, defined by SFN then, the MS randomly selects one access slot from the available access slots in the following frame, defined by SFN+1.

8) The MS transmits the access preamble using the MAC supplied uplink access slot, signature, and initial preamble transmission power P_{CPCH}.

9) If the MS does not detect any acquisition indicator (A1), as an acknowledgement corresponding to the selected signature in the downlink access slot corresponding to the selected uplink access slot, the MS:

a) Selects the next uplink access slot from among the access slots in the CPCH-AP sub-channel group. There must be a minimum distance of three or four access slots from the uplink access slot in which the last preamble was transmitted depending on the CPCH/AICH transmission timing parameter.

b) Increases the preamble transmission power by the specified offset ΔP. Power offset ΔP_0 is used unless the negative AICH timer is running, in which case ΔP_1 is used instead.

c) Retransmits access preamble using new parameters.

d) Decreases the Preamble Retransmission Counter by one.

e) If the Preamble Retransmission Counter<0, the MS aborts the access attempt and sends a failure message to the MAC layer.

10) If the MS detects a AP-AICH_NEG (negative acquisition indicator) corresponding to the selected signature in the downlink access slot corresponding to the selected uplink access slot, the MS aborts the access attempt and sends a failure message to the MAC layer. The MS sets the negative AICH timer to indicate use of ΔP_1 as the preamble power offset until the timer expires.

11) Upon reception of AP-AICH (positive access preamble acquisition indicator for the channel), the access segment ends and the contention or collision resolution segment begins. In this segment, the MS randomly selects a CD signature from the signature set and also selects one-CD access slot sub-channel from the CD sub-channel group supported in the cell and transmits a CD Preamble, then waits for a CD-AICH (collision detection-acquisition indicator channel) transmission by the BS.

12) If the MS does not receive a corresponding CD-AICH in the designated slot, the MS preamble from the base station aborts the access attempt and sends a failure message to the MAC layer.

13) If the MS receives a CD-AICH in the designated slot with a signature that does not match the signature used in the CD Preamble, the MS aborts the access attempt and sends a failure message to the MAC layer. This result indicates that the base station allocated the channel to another MS during the contention resolution phase.

14) If the MS receives a CD-AICH with a matching signature, the BS has selected this MS and assigned the requested CPCH resource to this MS. The MS transmits the power control preamble $\pi_{cd-p-pc-p}$ msec later as measured from initiation of the CD Preamble. The transmission of the message portion of the burst starts immediately after the power control preamble.

15) During CPCH Packet Data transmission, the MS and BS perform closed-loop power control on both the CPCH UL and the DPCCH DL.

16) If the MS detects a loss of DPCCH DL during transmission of the power control preamble or the packet data, the MS halts CPCH uplink transmission, aborts the access attempt and sends a failure message to the MAC layer elements.

17) If the MS completes the transmission of the packet data, the MS sends a success message to the MAC layer elements.

18) The MS will continue holding and using the CPCH channel if it receives more packets from the MAC in the midst of its uplink transmission.

FIG. **10** is a flow-chart illustrating a physical layer procedure for a BS access procedure. The procedure operates as outlined below.

First, the BS periodically or non-periodically broadcasts the availability of each CPCH channel or channel-group over a Status Broadcast Channel (S1). The availability information can be in the form of idle-ness or busy-ness or logical availability and may contain data rate availability information.

Upon detecting an access preamble (AP) from a mobile station (MS) requesting a CPCH channel (at S2), the base station (BS) sends out an acquisition indicator for the channel (AICH), which corresponds to the AP signature of the detected AP preamble. The BS sends the AP-AICH signal in a downlink access slot corresponding to the detected uplink access slot. At branch step S3, if the requested channel is available, the acquisition indicator is AP-AICH, indicating a positive response (S4). If the requested channel is not available, the acquisition indicator is AP-AICH_NEG, indicating a negative response (S5).

Upon detecting a CD Preamble from an MS (S6), the BS determines if there are two or more mobile stations requesting the available channel (S7). If multiple MS stations are requesting channel access, the BS selects one of those mobile stations (S8) and assigns the channel to the selected MS station by transmitting a CD-AICH (S9), which is a base station collision detection preamble that corresponds to the CD signature of the selected mobile station's CD Preamble. At the decision point S7, if there is only one MS requesting the available channel, the BS assigns the channel to the one MS by transmitting a CD-AICH which corresponds to the CD signature of that mobile station's CD Preamble (S10).

Upon receiving power control Preamble or packet data from a mobile station over an assigned channel (S11), the base station determines if there is one transmitting mobile station or multiple transmitting mobile stations (S12). If only one, then the base station transmits power control information on the DPCCH DL corresponding to the assigned channel (S13). However, if the determination at S12 indicates that there are multiple mobile stations transmitting over the assigned channel, then the BS ceases transmission on the corresponding DPCCH DL (S14) to instruct those mobile stations to abort transmissions over the assigned CPCH channel.

While the foregoing has described what are considered to be the best mode and/or other preferred embodiments of the invention, it is understood that various modifications may be made therein and that the invention may be implemented in various forms and embodiments, and that it may be applied in numerous applications, only some of which have been described herein. It is intended by the following claims to

claim any and all modifications and variations that fall within the true scope of the inventive concepts.

What is claimed is:

1. In a code-division-multiple-access (CDMA) system employing spread-spectrum modulation comprising a radio network controller, a plurality of base stations, each base station (BS) comprising a BS-spread-spectrum transmitter and a BS-spread-spectrum receiver, and a plurality of mobile stations, each mobile station (MS) comprising a MS-spread-spectrum transmitter and an MS-spread-spectrum receiver, a method comprising the steps of:

transmitting from the BS-spread-spectrum transmitter of one base station, a broadcast common-status channel, the broadcast common-status channel comprising data regarding current status as available for one or more channels from among a group of channels associated with the one base station;

receiving the broadcast common-status channel at an MS-spread-spectrum receiver of one mobile station, and selecting one of the channels of the group based on the broadcast available status data,

transmitting from an MS-spread-spectrum transmitter of the one mobile station an access-burst signal, the access-burst signal comprising a plurality of segments having a plurality of respective power levels;

receiving at the BS spread-spectrum receiver of the one base station at least one segment of the access-burst signal at a detectable-power level;

responsive to receipt of the at least one segment at the detectable power level, transmitting an acknowledgment signal from the BS-spread-spectrum transmitter of the one base station;

receiving the acknowledgment signal at the MS-spread-spectrum receiver of the one mobile station;

transmitting from the MS-spread-spectrum transmitter of the one mobile station a spread-spectrum signal comprising data and power control information, over the selected channel, responsive to the receipt of the acknowledgment signal; and

transmitting any of data and power control information, to the MS-spread-spectrum receiver from the BS-spread-spectrum transmitter of the one base station.

2. A method as set forth in claim 1, further comprising a collision resolution phase executed between the receipt of the acknowledgment signal and the transmission of the data by the one mobile station.

3. A method as set forth in claim 2, further comprising:

measuring traffic of the plurality of base stations and the plurality of mobile stations, at the radio network controller, to monitor traffic demand; and

assigning channel resources to the plurality of base stations by re-configuring the channel resources within each cell of each base station responsive to the monitored traffic demand.

4. A method as set forth in claim 2, wherein:

at least one of the transmissions from the BS-spread-spectrum transmitter of the one base station utilizes a downlink channel corresponding to the selected channel; and

if the MS-spread-spectrum receiver of the one mobile station detects a loss of the downlink channel, the MS-spread-spectrum receiver of the one mobile station halts any further transmission over the selected channel.

5. A method as in claim 2, wherein the collision resolution phase comprises:

transmitting from the MS-spread-spectrum transmitter of the one mobile station a spread-spectrum signal comprising a collision detection preamble;

receiving the collision detection preamble from the one mobile station at the BS spread-spectrum receiver of the one base station and substantially concurrently receiving a collision detection preamble from another mobile station at the BS spread-spectrum receiver of the one base station;

selecting the one mobile station for assignment of the selected channel;

transmitting from the BS-spread-spectrum transmitter of the one base station a base station collision detection preamble, the base station collision detection preamble corresponding to the collision detection preamble from the one mobile station; and

receiving the base station collision detection preamble at the MS-spread-spectrum receiver of the one mobile station,

wherein the step of transmitting a spread-spectrum signal comprising data from the MS-spread-spectrum transmitter of the one mobile station is responsive to the receipt of the base station collision detection preamble.

6. A method as in claim 2, wherein each segment of the access burst signal comprises a selected one of a group of access preamble signatures, the selected one signature corresponding to the selected channel.

7. A method as in claim 6, wherein acknowledgement signal corresponds to the selected one signature.

8. A method as set forth in claim 1, wherein the data regarding current status indicates an idle status for at least one channel from among a group of channels associated with the one base station.

9. A In a code-division-multiple-access (CDMA) system employing spread-spectrum modulation comprising a radio network controller, a plurality of base stations, each base station (BS) comprising a BS-spread-spectrum transmitter and a BS-spread-spectrum receiver, and a plurality of mobile stations, each mobile station (MS) comprising a MS-spread-spectrum transmitter and an MS-spread-spectrum receiver, a method comprising the steps of:

transmitting from the BS-spread-spectrum transmitter of one base station, a broadcast common-status channel, the broadcast common-status channel comprising data regarding the availability or available data rates for one or more channels of a group of channels associated with the one base station;

receiving the broadcast common-status channel at an MS-spread-spectrum receiver of one mobile station, and selecting one of the channels of the group based on the data regarding broadcast availability or available data rates;

transmitting from an MS-spread-spectrum transmitter of the one mobile station an access-burst signal, the access-burst signal comprising a plurality of segments having a plurality of respective power levels;

receiving at the BS spread-spectrum receiver of the one base station at least one segment of the access-burst signal at a detectable-power level;

responsive to receipt of the at least one segment at the detectable power level, transmitting an acknowledgment signal from the BS-spread-spectrum transmitter of the one base station;

receiving the acknowledgment signal at the MS-spread-spectrum receiver of the one mobile station;

transmitting from the MS-spread-spectrum transmitter of the one mobile station a spread-spectrum signal comprising data and power control inflation, over the selected channel, responsive to the receipt of the acknowledgment signal;

executing a collision resolution phase between the receipt of the acknowledgment signal and the transmission of the data by the one mobile station; and

transmitting any of data and power control information, to the MS-spread-spectrum receiver, from the BS-spread-spectrum transmitter of the one base station, wherein:

the one mobile station initiates the step of receiving and selecting when the one mobile station has a first data packet to send, and

the step of transmitting the spread-spectrum signal comprising data, over the selected channel, comprises piggybacking at least one additional packet that becomes ready-to-send immediately after transmission of the first data packet.

10. A code-division-multiple-access (CDMA) wireless base station, comprising:

a CDMA transmitter;

a CDMA receiver; and

a controller coupled to the CDMA receiver for responding to signals received via the CDMA receiver and coupled for controlling the CDMA transmitter, such that in operation the CDMA base station is for performing the following steps:

transmitting a broadcast common-status channel, the broadcast common-status channel comprising availability-related status information for one or more channels of a group of common packet channels allocated to the base station;

receiving from a remote station an access burst over one of the common packet channels, the access burst comprising a sequence of coded preamble signals at sequentially increasing discrete power levels, each coded preamble signal in the sequence comprising one of a plurality of possible signature codes, the one signature code corresponding to the one common packet channel as selected from the group by the remote station based on the status information;

detecting a first one of the coded preamble signals of the sequence that is received at an adequate power level;

upon detection of the first coded preamble signal at the adequate power level, transmitting an acknowledgement signal corresponding to the one signature code; and

receiving any of data and power control information over the one common packet channel from the remote station.

11. A CDMA wireless base station as set forth in claim **10**, wherein:

the controller is further responsive to the CDMA receiver and controls the CDMA transmitter, such that in operation the CDMA base station performs a collision resolution phase after transmitting the acknowledgement signal, the collision resolution phase comprising the following steps:

receiving from the remote station a first remote station collision detection preamble;

substantially concurrently receiving from another remote station a second remote station collision detection preamble; and

transmitting a base station collision detection preamble corresponding to the first remote station collision detection preamble.

12. A CDMA wireless base station as in claim **11**, wherein the controller is further responsive to the CDMA receiver and controls the CDMA transmitter such that in operation the CDMA base station performs a power control phase after transmitting the base station collision detection preamble and before receiving the data over the one common packet channel.

13. A CDMA wireless base station as in claim **10**, wherein the controller is further responsive to the CDMA receiver and controls the CDMA transmitter to send any of data and power control information for the remote station.

14. The CDMA wireless base station as in claim **10**, wherein the availability-related status information comprises at least one of:

data regarding availability of one or more channels from among the group of common packet channels allocated to the base station, and

data regarding available data rates for one or more channels of the group of common packet channels allocated to the base station.

15. A code-division-multiple-access (CDMA) wireless remote station, comprising:

a CDMA transmitter;

a CDMA receiver; and

a controller coupled to the CDMA receiver for responding to signals received via the CDMA receiver and coupled for controlling the CDMA transmitter, such that in operation the CDMA remote station is for performing the following steps:

receiving from a base station a broadcast common-status channel, the broadcast common-status channel comprising availability-related status information for one or more channels of a group of common packet channels served through the base station;

selecting one common packet channel from the group based on the status information;

transmitting an access burst over the one common packet channel, the access burst comprising a sequence of coded preamble signals at sequentially increasing discrete power levels, each coded preamble signal in the sequence comprising one of a plurality of possible signature codes, the one signature code corresponding to the selected common packet channel;

receiving an acknowledgement signal from the base station over a downlink channel corresponding to the one common packet channel following the transmission of one or more of the coded preamble signals, the acknowledgement signal corresponding to the signature code;

transmitting data over the one common packet channel following receipt of the acknowledgement signal; and

receiving any of data and control information from the base station over a downlink channel corresponding to the one common packet channel.

16. A CDMA wireless remote station as in claim **15**, wherein the controller is further responsive to the CDMA receiver and controls the CDMA transmitter, such that in operation the CDMA remote station performs a collision resolution phase after receiving the acknowledgement signal, the collision resolution phase comprising the following steps:

transmitting a randomly generated remote station collision detection preamble; and

receiving a base station collision detection preamble corresponding to the remote station collision detection preamble, and

wherein the step of transmitting data is responsive to the receipt of the corresponding base station collision detection preamble.

17. A CDMA wireless remote station as in claim 15, wherein:

the controller is further responsive to the CDMA receiver and controls the CDMA transmitter, such that in operation if the CDMA remote station detects a loss of the downlink channel, the MS-spread-spectrum receiver of the CDMA remote station halts any further transmission over the one common packet channel.

18. The CDMA wireless remote station as in claim 15, wherein the received availability-related status information comprises at least one of:

data regarding availability of one or more channels from among the group of common packet channels served through the base station; and

data regarding available data rates for one or more channels of the group of common packet channels served through the base station.

19. A code-division-multiple-access (CDMA) wireless remote station, comprising:

a CDMA transmitter;

a CDMA receiver; and

a controller coupled to the CDMA receiver for responding to signals received via the CDMA receiver and coupled for controlling the CDMA transmitter, such that in operation the CDMA remote station is for performing the following steps:

receiving from a base station a broadcast common-status channel, the broadcast common-status channel comprising availability-related status information for one or more channels of a group of common packet channels served through the base station;

selecting one common packet channel from the group based on the status information;

transmitting an access burst over the one common packet channel, the access burst comprising a sequence of coded preamble signals at sequentially increasing discrete power levels, each coded preamble signal in the sequence comprising one of a plurality of possible signature codes, the one signature code corresponding to the selected common packet channel;

receiving an acknowledgement signal from the base station over a downlink channel corresponding to the one common packet channel following the transmission of one or more of the coded preamble signals, the acknowledgement signal corresponding to the signature code;

transmitting data over the one common packet channel following receipt of the acknowledgement signal; and

receiving any of data and control information from the base station over a downlink channel corresponding to the one common packet channel, wherein:

the controller initiates the step of selection of the one common packet channel when the remote station has a first data packet to send, and

the controller is further for controlling the transmission of data over the one common packet channel so as to piggy-back at least one additional packet that becomes ready-to-send immediately after transmission of the first data packet.

20. A base-band processor, for use in a code-division-multiple-access (CDMA) wireless base station having a modulator and a demodulator, the base-band processor comprising:

a preamble processor, coupled to the demodulator, for detecting a preamble in a received spread-spectrum signal;

a data processor, coupled to the demodulator, for detecting and processing any data contained in the received spread-spectrum signal;

an encoder, for encoding data;

an interleaver, coupled to the encoder, for interleaving encoded data;

a packet formatter, coupled to the interleaver, for formatting the interleaved data into a packet; and

a controller coupled to the preamble processor and coupled for controlling the modulator, the data processor and the packet formatter, such that in operation the base-band processor is for performing the following steps:

transmitting a broadcast common-status channel, the broadcast common-status channel comprising availability-related status information for one or more channels of a group of common packet channels allocated to the base station;

receiving from a remote station an access burst over one of the common packet channels, the access burst comprising a sequence of coded preamble signals at sequentially increasing discrete power levels, each coded preamble signal in the sequence comprising one of a plurality of possible signature codes, the one signature code corresponding to the one common packet channel as selected from the group by the remote station based on the status information;

detecting a first one of the coded preamble signals of the sequence that is received at an adequate power level;

upon detection of the first coded preamble signal at the adequate power level, transmitting an acknowledgement signal corresponding to the one signature code;

receiving data over the one common packet channel from the remote station; and

transmitting any of data and control information to the remote station.

21. A base-band processor as set forth in claim 20, wherein,

the controller is further arranged such that in operation the base-band processor is for performing a collision resolution phase after transmitting the acknowledgement signal, the collision resolution phase comprising the following steps:

receiving from the remote station a first remote station collision detection preamble;

substantially concurrently receiving from another remote station a second remote station collision detection preamble; and

transmitting to the remote station a base station collision detection preamble corresponding to the first remote station collision detection preamble.

22. A base-band processor as in claim 21, wherein the controller is further arranged such that in operation the base-band processor is for performing a power control phase prior to receiving and transmitting data.

23. The base-band processor as in claim 20, wherein the availability-related status information comprises at least one of:

data regarding availability of one or more channels from among the group of common packet channels allocated to the base station, and

data regarding available data rates for one or more channels of the group of common packet channels allocated to the base station.

24. A base-band processor, for use in a code-division-multiple-access (CDMA) wireless remote station having a spread-spectrum modulator and a spread-spectrum demodulator, the base-band processor, comprising:

an acknowledgment detector, coupled to the demodulator, for detecting an acknowledgment in a received spread-spectrum signal;

an encoder, for encoding data;

an interleaver, coupled to the encoder, for interleaving encoded data;

a preamble generator for generating a preamble;

a multiplexer, coupled to the interleaver and to the preamble generator, for multiplexing the interleaved data and the preamble;

a packet formatter, coupled to the multiplexer, for formatting the multiplexed data and preamble into one or more packets; and

a controller coupled to the acknowledgment detector and coupled for controlling the modulator, the preamble generator, the multiplexer and the packet formatter, such that in operation the base-band processor is for performing the following steps:

receiving from a base station a broadcast common-status channel, the broadcast common-status channel comprising availability-related status information for one or more channels of a group of common packet channels served through the base station;

selecting one common packet channel from the group based on the status information;

transmitting an access burst over the one common packet channel, the access burst comprising a sequence of coded preamble signals at sequentially increasing discrete power levels, each coded preamble signal in the sequence comprising one of a plurality of possible signature codes, the one signature code corresponding to the selected common packet channel;

receiving an acknowledgement signal from the base station following the transmission of one or more of the coded preamble signals, the acknowledgement signal corresponding to the one signature;

transmitting data over the one common packet channel following receipt of the corresponding acknowledgement signal; and

receiving any of data and control information from the base station.

25. A base-band processor as in claim 24, wherein:

the controller is further arranged such that in operation the base-band processor is for performing a collision resolution phase after receiving the acknowledgement signal, the collision resolution phase comprising the following steps:

transmitting a randomly generated remote station collision detection preamble;

receiving a base station collision detection preamble corresponding to the remote station collision detection preamble; and

initiating the step of transmitting the data over the one common packet channel in response to the receipt of the base station collision detection preamble.

26. A base-band processor as in claim 24, wherein:

the controller initiates the step of selection of the one common packet channel when the remote station has a first data packet to send, and

the controller is further for controlling the transmission of data over the one common packet channel so as to piggy-back at least one additional packet that becomes ready-to-send immediately after transmission of the first data packet.

27. The base-band processor as in claim 24, wherein the received availability-related status information comprises at least one of:

data regarding availability of one or more channels from among the group of common packet channels served through the base station; and

data regarding available data rates for one or more channels of the group of common packet channels served through the base station.

28. In a code-division-multiple-access (CDMA) system employing spread-spectrum modulation comprising a radio network controller, a plurality of base stations, each base station (BS) comprising a BS-spread-spectrum transmitter and a BS-spread-spectrum receiver, and a plurality of mobile stations, each mobile station (MS) comprising a MS-spread-spectrum transmitter and a MS-spread-spectrum receiver, a method comprising the steps of:

transmitting from the BS-spread-spectrum transmitter of one base station, a broadcast common-status channel, the broadcast common-status channel comprising data regarding available data rates for one or more channels of a group of channels associated with the one base station;

receiving the broadcast common-status channel at an MS-spread-spectrum receiver of one mobile station, and selecting one of the channels of the group based on the available data rates data;

transmitting from an MS-spread-spectrum transmitter of the one mobile station an access-burst signal, the access-burst signal comprising a plurality of segments having a plurality of respective power levels;

receiving at the BS spread-spectrum receiver of the one base station at least one segment of the access-burst signal at a detectable-power level;

responsive to receipt of the at least one segment at the detectable power level, transmitting an acknowledgment signal from the BS-spread-spectrum transmitter of the one base station;

receiving the acknowledgment signal at the MS-spread-spectrum receiver of the one mobile station;

transmitting from the MS-spread-spectrum transmitter of the one mobile station a spread-spectrum signal comprising data and power control information, over the selected channel, responsive to the receipt of the acknowledgment signal; and

transmitting any of data and power control information, to the MS-spread-spectrum receiver, from the BS-spread-spectrum transmitter of the one base station.

29. A method as set forth in claim 28, wherein the broadcast common-status channel further comprises data regarding the availability of one or more channels from among the group of channels associated with the one base station.

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